SAFETY OF LIGHT COMMERCIAL VEHICLES IN THE LIGHT OF THE RESULTS OF ACCIDENT ANALYSES AND TESTING

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ABSTRACT

Light transport vehicles are becoming more important in the European vehicle fleet. There is a growing public interest in the safety of delivery vans as they become increasingly regarded as the workplace of the drivers. To date, only little attention has been given to the accident involvement and to the safety performance of such vehicles both from the research and the regulatory point of view.

Official statistics give an overview of the growth of the number of these vehicles and their accident involvement. More detailed accident analyses using in-depth studies are presented from analysis of cases collected by DEKRA and the Ford light truck accident study. These analyses have highlighted particular items of interest such as crash configurations, injury severity, restraint use and compatibility. The occupant safety of current delivery vans is described by the results of crash tests and brake tests carried out by DEKRA. Crash tests were carried out at a full frontal impact at 48 km/h (according to FMVSS 208 / 301). In another test, the vehicle was crashed at 56 km/h with 40 % overlap (according to ECE-R 94). The responses from occupant dummies show low injury risk and reasonable structural behaviour. Brake tests according to ECE Regulation 13 show that the brake performance of current delivery vans is nearly the same as for cars.
The authors highlight some areas of future consideration for improving the operational safety of light goods vehicles.

INTRODUCTION

Light goods vehicles/delivery vans belong to the group of transport vehicles with the highest growth rate in Europe over the last few years, with respect to the number of registered vehicles (RÜCKER et. al., 2002). More and more goods are being delivered directly to the customer's doorstep in the shortest possible time. Postal express and courier service companies have successfully established themselves in this sector, mainly using small and medium-sized vans. In an effort to adapt to the changing requirements, the equipment and engine power of such vans have been improved. Nowadays, vans are capable of achieving speeds of over 150 km/h – a range which was formerly only attained by cars. In Germany, delivery vans have become increasingly involved in accidents and police traffic surveillance controls in the last few years. It is one of the tasks of accident research to illustrate the actual situation with the aid of scientifically proven facts, thus bringing more rational arguments into the discussion. The increasing number of small vans involved in accidents and registered by police enforcement cameras can be mainly attributed to the increased number of this type of vehicle now on the road. Scientifically founded and more detailed studies on the accident involvement of small and medium-size vans are very scarce to date. At best, the studies known to us only broach to the subject superficially.

At the end of the 1990s, DEKRA's accident research division started studying the accident involvement of small and medium-sized vans (NIEWÖHNER et al., 2000; NIEWÖHNER et al., 2001). Since then, this research has been continued with a larger number of study cases. The present paper also includes additional research carried out for Ford's accident research department on light goods vehicle accidents in Great Britain. This has been supplemented by crash tests carried out on vans at the DEKRA Crash Centre and braking tests carried out at the DEKRA Automobil Testing Centre. In this way, real evidence is provided on the status quo of the safety of this class of vehicle. Publications dealing with this subject which have been issued by other institutions have been collected and are included in the discussion.

DEFINITION OF SMALL AND MEDIUM-SIZED GOODS VEHICLES (DELIVERY VANS)

In Germany, vans can be registered either as trucks (*Lastkraftwagen – Lkw*) or as private passenger vehicles (*Personenkraftwagen – Pkw*). In this respect, specific definitions and characteristics have to be observed (RÜCKER et al., 2002). Motor vehicles (MVs) with a permitted gross mass above 3.5 tonnes have to observe specific speed limits even outside of urban areas (§ 3 of the German road traffic legislation – StVO). Motor vehicles with a permitted gross weight of more than 7.5 tonnes must be fitted with a tachograph which can be officially calibrated to register the vehicle's speed and the drivers' working and rest times (§ 27a of the German legislation for approval of vehicles for public road traffic – StVZO). Apart from this, holders of an older German driving permit Class 3 (*"Pkw"*) are allowed to drive motor vehicles of a permitted gross weight of up to 7.5 t, without needing a special truck or lorry driver's permit.

In the sense of the present paper, small and medium-sized goods vehicles are the so-called "vans" in which the driver's cabin and the luggage compartment are an integral unit. The interior of these vehicles usually have a partition or bars to protect the driver and passenger(s) from the load being transported. We can distinguish between small vans of up to 3.5 t permitted gross mass (Figure 1) and large vans of between 3.5 t and 7.5 t permitted gross mass (Figure 2).

Figure 1: small vans

Figure 2: large vans

NUMBER OF VEHICLES REGISTERED AND NUMBER OF RELATED ACCIDENTS, ACCORDING TO OFFICIAL STATISTICS

Since light goods vehicles and vans do not form a completely separated vehicle category *(in Germany)*, it is not possible to determine accurately from official statistics the number of such vehicles registered or the number of them involved in accidents. However, the figures which are available for trucks and which are categorised by maximum permitted gross mass do provide some indications.

Number of vehicles registered

Figure 3 shows the figures for the numbers of vans, trucks and articulated truck traction units registered in Germany as trucks, as published by the German Federal Motor Vehicle Bureau (*Kraftfahrtbundesamt – KBA*) for the 1st of July of the respective years from 1986 up to 2001. In this figure, the vehicles are categorised according to permitted gross mass: vans up to 3.5 t, vans ranging from 3.51 t to 7.5 t and vans/trucks, including articulated truck traction units, above 7.5 t.

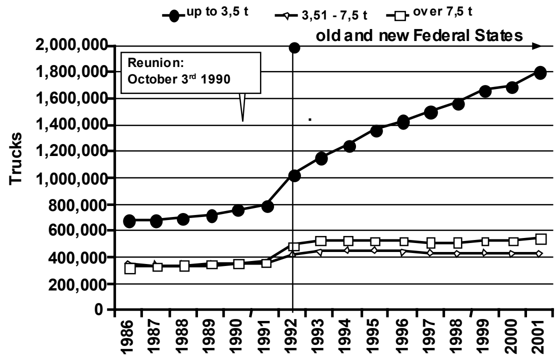

Figure 3: Development of the number of registered vans of permitted gross mass up to 3.5 t, between 3.5 t and 7.5 t and trucks, including articulated truck traction units, above 7.5 t.

The figures published by the KBA include the vehicles registered in the new Federal States (former East Germany) only as from 1992 onwards. A rapid rise in the numbers of all three vehicle groups can be identified as being the result of German reunification in October 1990, especially as the area covered by the statistics has increased. In the medium-sized goods vehicle (3.51 t - 7.5t) and large goods vehicle (over 7.5 t) this rate of increase did not continue after 1992, but the registered number of vans of permitted gross weight up to 3.5 t continued to rise steadily in the ensuing years. From 1992 to 2001, the number of registered vans of permitted gross weight up to 3.5 t increased by 774,808 vehicles, or 75 %. These figures mirror the considerable increase in small van sales reported by vehicle manufacturers.

Accident statistics

The German Federal Statistics Bureau (*Statistisches Bundesamt – StBA*) publishes figures on the numbers and types of vehicles involved in accidents. Accidents occurring in the new Federal

States were already included from 1991 onwards. In relationship to vans, the so-called motorised goods transport vehicles (*Güterkraftfahrzeuge*) involved in accidents leading to personal injuries are of interest. In these statistics, vans and trucks with and without trailers are listed according to their permitted gross mass (up to 3.5 t, 3.5 t - 7.5 t and above 7.5 t). In the StBA statistics, articulated truck traction units (called articulated trucks in the StBA figures) are treated as a separate category. These are mainly heavy goods vehicles which can be categorised as trucks above 7.5 t permitted gross weight.

Figure 4 shows the development of the related numbers of accidents within urban areas in the 1986 - 2001 period. As can be seen, the number of vans of the light vehicle class of up to 3.5 t involved increased by 4,818, corresponding to 64 % (from 1992 to 2001).

On country roads other than Federal motorways (Autobahnen), the number of vans of the light vehicle class up to 3.5 t involved in accidents with casualties increased even more noticeably, namely by 2,716, or 79 % (from 1992 to 2001), as illustrated in Figure 5. In these figures, the number of light vehicles (up to 3.5 t) exceeds the number of medium-sized trucks (3.5 t - 7.5 t) involved in accidents of this kind from 1999 onwards.

On Federal motorways (Autobahnen), the number of vans of the light goods vehicle class up to 3.5 t involved in accidents with casualties increased by 948, or 80 % (from 1992 to 2001), as illustrated in Figure 6. However, in this particular type of accident location, large goods vehicles of permitted gross mass above 7.5 t, including articulated trucks, continue to dominate.

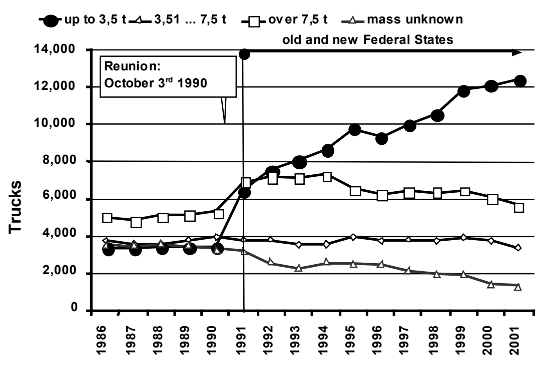

Figure 4: Development of number of vans/ trucks with permitted gross mass up to 3.5 t, between 3.5 t and 7.5 t and above 7.5 t (including articulated trucks) involved in accidents with casualties inside urban areas in Germany during the period 1986 to 2001 (source: StBA)

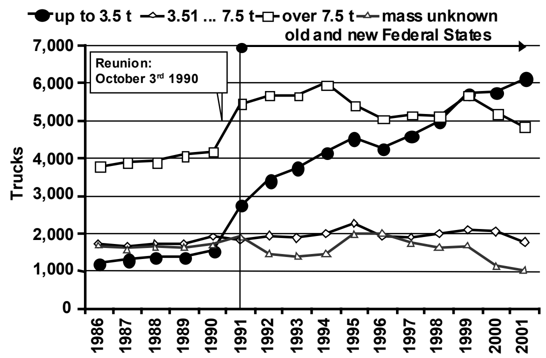

Figure 5: Development of numbers of vans/ trucks with permitted gross mass up to 3.5 t, between 3.5 t and 7.5 t and above 7.5 t (including articulated trucks) involved in accidents with casualties on country roads, excluding motorways, in Germany during the period 1986 to 2001 (source: StBA)

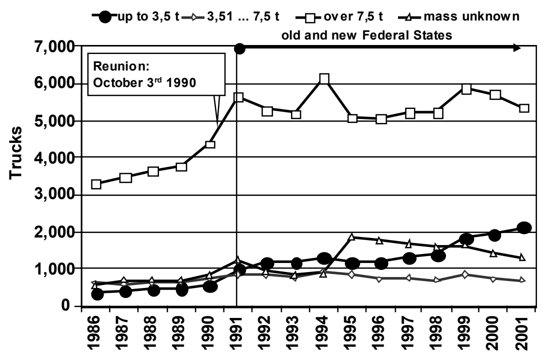

Figure 6: Development of numbers of vans/ trucks with permitted gross mass up to 3.5 t, between 3.5 t and 7.5 t and above 7.5 t (including articulated trucks) involved in accidents with casualties on motorways in Germany during the period 1986 to 2001 (source: StBA)

It is not possible to determine more accurate information on the involvement of vans (light transport vehicles) from the figures contained in the official statistics. Apart from this, it is not possible to include those vans registered as private cars in this separate statistical analysis. However, we may safely sum up by concluding that both the absolute and relative involvement of vans with a permitted gross mass up to 3.5 t in accidents in Germany has increased considerably since the beginning of the 1990s. This corresponds to the increase of the number of vehicles of this category registered in the respective period.

The available official statistics give no indications that the risk of any individual van becoming involved in an accident has increased, too. Due to their increasing use in courier and express postal services, an increase in the specific mileage of these vehicles can be assumed. It is thus justifiable to assume that the accident risk of vans has even shown a tendency to decrease with respect to the specific vehicle mileage. Unfortunately, no scientifically founded data on the accident risk of vans in relation to the specific mileage of such vehicles are currently known.

RESULTS OF IN-DEPTH STUDIES CARRIED OUT BY DEKRA'S ACCIDENT RESEARCH DIVISION

In spite of this, the considerable increase in the number of accidents involving vans is reason enough for accident research organisations to investigate the accident involvement of such vehicles thoroughly.

In investigating real accident events, DEKRA's accident research division (*DEKRA Unfallforschung*) makes use of accident analysis reports. A large number of these reports are compiled all over Germany by specially trained experts, mainly by order of state prosecutors and courts. They serve to clarify how the accidents developed and contain comprehensive technical reconstructions of the events, including observations on how the respective accident could have been avoided, as well as supplementary information. The cases studied here comprise a sub-set of all accidents some of which are included in the official statistics whilst others are not officially reported (GRANDEL et al. 1996). Depending on the objectives of the respective project, DEKRA accident research staff may co-operate with medical staff, while observing data confidentiality requirements, in order to supplement the information in the reports, which is mainly of a technical nature, with medical data – particularly concerning the type and severity of injuries (BERG et al., 2002).

In 1999, the division started to compile a database on accident events in which vans (goods vehicles with permitted gross masses up to 7.5 t) were involved (NIEWÖHNER et al., 2000 and 2001). At present, this database contains data on 186 cases which occurred between 1995 and 2001. 96 % of the goods vehicles in the cases investigated had a permitted gross mass of 3.5 t or less.

Comparison of the cases studied by DEKRA to the official statistics

In 166 of the cases studied by DEKRA, the accident location is exactly known.

Figure 7 shows their distribution in comparison to the distribution of all 27,932 accidents in which vans of a permitted gross mass up to 3.5 t were involved, as recorded by official StBA statistics in 2001. Of these 27,932 recorded accidents, 20,678 led to injuries to persons and 7,254 were associated with severe material damage (in the more exacting definition according to the StBA). The bar chart shows that the majority of the cases studied by DEKRA occurred on country roads and on motorways (Autobahnen).

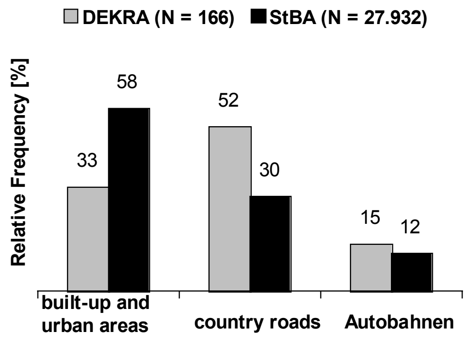

Figure 7: Comparison of locations of 166 transport vehicle accidents (in DEKRA database) to the locations of 27,932 accidents with casualties and severe material damage occurring in Germany in 2001 and involving vans of a permitted gross mass of up to 3.5 t (StBA)

In 139 of the cases studied by the DEKRA accident research team, information was available on the severity of the injuries incurred by persons involved in the accidents. A comparison with the severity figures of the 27,932 accidents registered by the StBA for the year 2001 shows that the cases studied by DEKRA contained a higher proportion of severe injuries and fatalities, as illustrated by Figure 8.

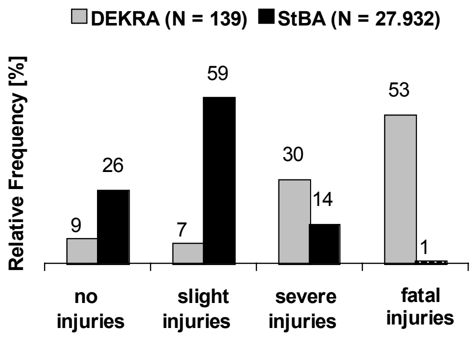

Figure 8: Comparison of the severity of 139 goods vehicle accidents (in DEKRA database) to the locations of 27,932 accidents with casualties and severe material damages occurring in Germany in 2001 and involving vans of a permitted gross mass up to 3.5 t (StBA)

This is because the commissioning of experts to analyse accident occurrences is governed by the cost/benefit relationship. As a result, experts are more frequently called in to investigate the more serious accidents. Due to the higher speeds leading to accidents of this kind, these mainly occur outside of urban and built-up areas, and on motorways (Autobahnen). This means that DEKRA accident research focuses more strongly on serious accidents.

In the 166 cases where the month of the accident was known and recorded in the DEKRA database, an aggregation in the warmer part of the year is to be observed, Figure 9. This is also visible in the distribution of the 27,932 accidents with casualties involving vans of a permitted gross mass up to 3.5 t, as registered by the StBA for the year 2001.

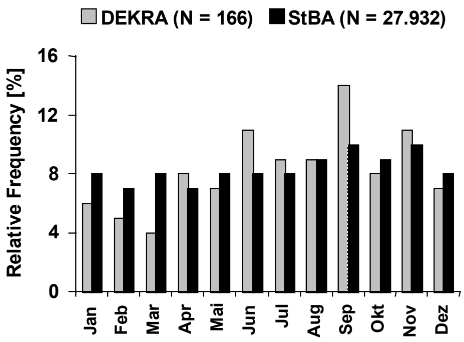

Figure 9: Monthly distribution of 166 transport vehicle accidents (in DEKRA database) and of 27,932 accidents leading to casualties and severe material damages occurring in Germany in 2001 and involving vans of a permitted gross mass up to 3.5 t (StBA)

Other detail characteristics of the cases studied by DEKRA

The time of day when the accident occurred is known for 163 of the cases studied by DEKRA. The corresponding distribution chart shows distinct aggregations in the periods 6-8 a.m., 10-12 a.m. as well as 2-4 p.m. and 4-6 p.m., Figure 10.

In accordance with their majority status in road traffic, private cars were the type of vehicle most frequently involved in collisions with vans, i.e. in 45 % of all cases, Figure 11. These are followed by accidents involving the van alone (13 %) and then by accidents between vans and heavier trucks of a permitted gross mass of over 7.5 t (13 %).

The most frequent accident type – also termed "situation leading to accident" – in which vans were involved was found to be the accident in the direction of traffic flow, as shown in Figure 12. In second place, with 23 % of all accidents, are turning-off / road crossing accidents. Third in the frequency rating are accidents in which the driver lost control over the vehicle, constituting 16 % of all occurrences.

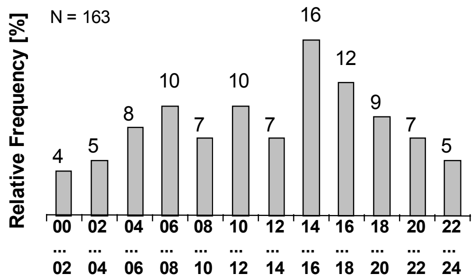

Figure 10: Distribution of 163 van accidents over the time of day (DEKRA database)

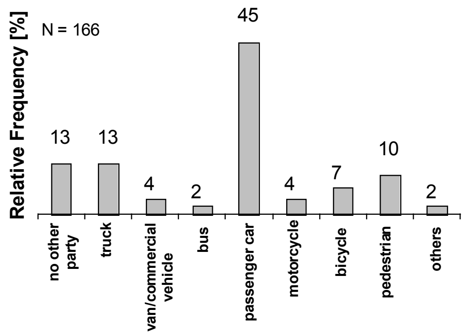

Figure 11: Distribution of other parties involved in accidents, data for 166 van accidents (DEKRA database)

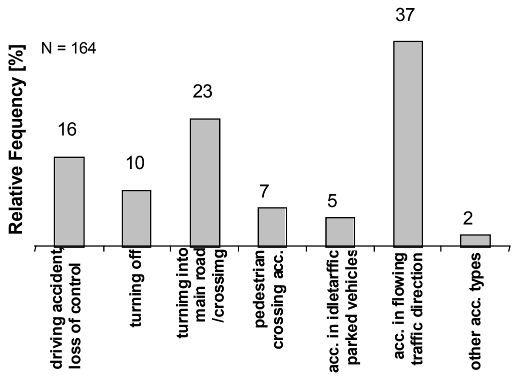

Figure 12: Accident types, data for 164 van accidents (DEKRA database)

It was possible to reconstruct the collision situations of 158 of the van accident cases. The results are shown in Figure 13. The majority of cases are frontal van collisions. In 29 % of all cases, the front of the van collided with the side of the other vehicle involved, in 25 % with the front and in 11 % with the rear of the other vehicle. Side-swiping collisions (where the sides of both vehicles involved in the accident touch) and accidents involving the van alone, both with a proportion of 8 %, come fourth.

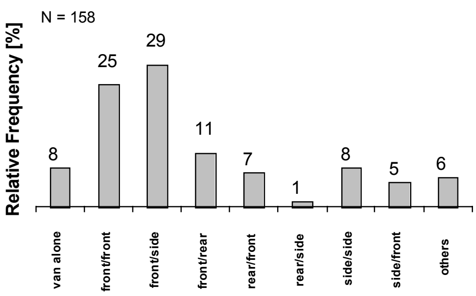

Figure 13: Collision situation of 158 accidents in which vans were involved (DEKRA database)

Vehicle speed and collision speed

In 151 cases it was possible to reconstruct the speed at which the vans were travelling immediately before the accident occurred, and in 150 cases it was possible to determine the collision speed. Figure 14 shows the cumulative frequency for all road types. A cumulative frequency of approximately 70 % is achieved by vehicle speeds in the 71 to 80 km/h range and by collision speeds in the 61 to 70 km/h range.

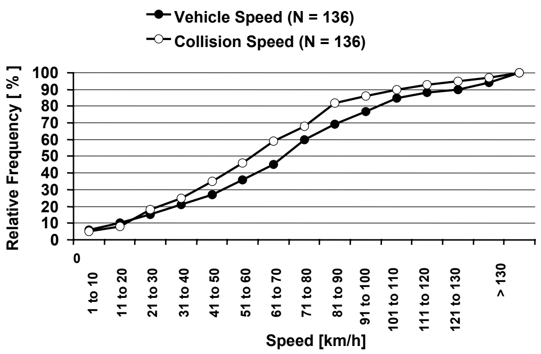

Figure 14: Cumulative frequency of the speeds at which 151 vans were travelling immediately before the accident and of the collision speeds of 150 vans, both on all road types (DEKRA database)

In five cases (3 %), vehicle speeds of over 130 km/h were observed. As this is a speed currently under discussion as a possible speed limit for goods vehicles with a permitted gross mass of up to 3.5 t, these cases were investigated in more detail. One of the accidents was a frontal collision with an on-coming truck and occurred during daylight hours on a country road. Here, there are indications that the van's driver was excessively tired. Three of these accidents occurred on motorways and involved two or more vehicles, the van running into the rear of a truck travelling ahead of it. The fourth motorway accident was a single-vehicle accident due to a burst tyre. Two of the motorway accidents occurred between 2:25 and 6:00 a.m. and the other two accidents occurred during daylight hours. The accident development situations of the three front/rear collisions give reason to believe that the respective drivers had been careless or had even fallen asleep.

In all five cases, the accidents would have occurred in virtually the same way and very probably had the same severity if the speed had been limited to 130 km/h. This shows that no useful potential for limiting the speed of light goods vehicles to 130 km/h can be deduced from these study cases.

Distribution of the responsibilities for the accidents

Drivers of vans with a permitted gross mass of up to 3.5 t are clearly overrepresented in an analysis of official statistics to determine the ratio of main parties to blame per 1000 persons involved in road accidents, as illustrated in Figure 15. An above-average number of van drivers were found to be the main person responsible for accidents in both 1992, when the ratio was 585/1000, and in 2001, when the ratio was 630/1000 for all registered persons involved in accidents. A similar situation can be observed for vans of a permitted gross mass of 3.5 t to 7.5 t (1992: 598 main accused persons per 1000 persons involved, 2001: 601 main persons accused per 1000 persons involved). Seen in relationship to the known number of vehicles registered and the recorded number of accidents, these figures show that drivers of delivery vehicles have been very frequently responsible for causing accidents.

In accidents involving vans/trucks over 7.5 t permitted gross mass, it was found that the drivers were the main parties to blame in 515 and 525 cases per 1000 persons involved, respectively. The corresponding figures for drivers of articulated trucks were 502 and 518, which is quite close to the average of 500. Bus drivers are the main person responsible in only 389 and 395 cases per 1000 persons involved, respectively, this being far below the average value.

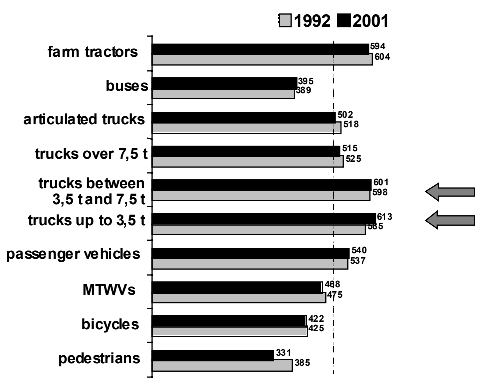

Figure 15: Main person responsible for causing accidents with casualties, per 1000 persons involved in accidents, for the years 1992 and 2001 (source: StBA)

The cases recorded in the official statistics include both single-vehicle accidents (in which the driver of the vehicle is usually at fault) and accidents involving two or more parties.

In this context, 166 of the cases studied by DEKRA in which two vehicles were involved were investigated to determine whether, in the opinion of the accident research experts, the driver of the transport vehicle was wholly responsible, mainly responsible, only partly responsible (approximately 50:50) or hardly or not at all responsible for the accident. Figure 16 shows the results of this analysis. This shows that there is a tendency for the transport vehicle driver to be more frequently at fault than the other person(s) involved in the accident.

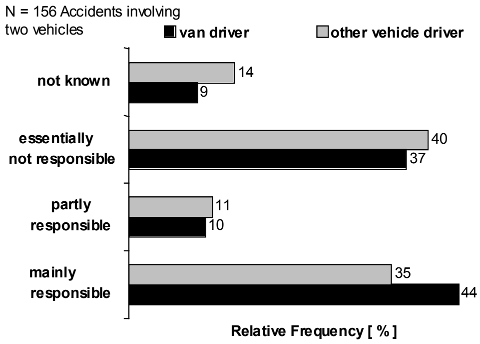

Figure 16: Distribution of the responsibility for 156 two-vehicle accidents involving vans, according to experts' opinions (DEKRA database)

In agreement with the deductions drawn from the StBA statistics, potential benefits can be expected from corrective measures concerning drivers. This is already reflected in the training required to obtain the respective driving permits for buses and large trucks/heavy goods vehicles (HGVs). Supplementary training of van drivers should also be provided, for example regular discussions on safety-relevant matters such as compliance with regulations on driving (working) hours and rest periods etc. at meetings of the vehicle fleet drivers.

Severity of injuries and use of safety belts

The 166 van accidents recorded in the DEKRA database also involved 237 front-seat passengers of these vehicles. It was possible to determine the severity of the injuries suffered by 201 of these 237 occupants. Approximately 60 % of them sustained injuries of which 30 % could be classified as severe injuries. 17 % of the passengers and drivers sustained slight injuries and 14 % sustained fatal injuries.

Some of the relatively frequent and severe injuries can be obviously attributed to the low utilisation of safety belts. For 73 occupants, it was possible to conclusively determine whether he/she wore a seat belt or not, Figure 18. Approximately half of these drivers and passengers (49 %) were not wearing a seat belt. Among the unbelted persons about 89 % sustained serious or fatal injuries whereas only 59 % of people who were wearing a seat belt sustained these injuries.

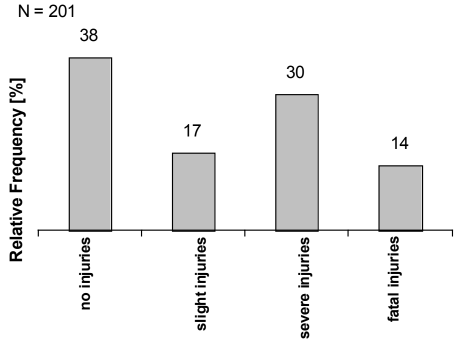

Figure 17: Severity of injuries to 201 front-seat van passengers (DEKRA database)

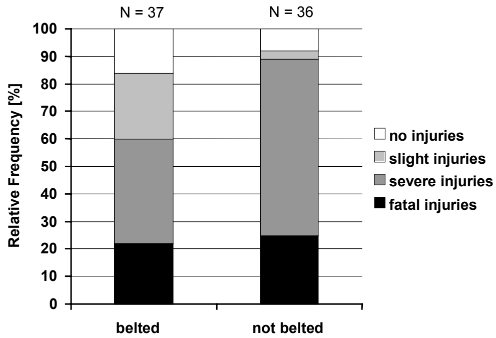

Figure 18: Safety belt usage by 73 van passengers, according to injury severity (DEKRA database)

FINDINGS OBTAINED BY FORD'S ACCIDENT RESEARCH TEAM

The following section contains detailed evaluations and results of an in-depth collection of data of nearly 500 van accidents in Great Britain. This study is part of Ford's European accident research effort, it was commissioned by Ford and carried out by the Vehicle Safety Research Centre of the University of Loughborough. The accident database, which has been in existence for ten years now, mainly contains data on delivery vans (permitted gross mass up to 3.5 t), car-derived vans (e.g. Ford Escort and Courier) and minibuses. To select the relevant cases from the entire set of accidents recorded, two exclusion criteria were applied:

- the vehicle involved (van) needed to be towed away following the accident because of the damage sustained,
- at least one of the persons involved must have been injured during the accident.

In principle therefore, the set of accidents studied is subject to random sampling. Most of the vehicles involved were less than six years old when the accident occurred. The injuries are classified according to the “abbreviated injury scale” (AIS system, 1990 – AAAM, 1990). LENARD et al. published a detailed description of this study in 2002.

The British national accident statistics (RAGB, 2000) provide an important indicator for analysing light goods vehicle (LGV) accidents from “in-depth data surveys”. If we compare the proportion of LGV drivers killed in accidents to the proportion of passenger car and bus drivers killed in accidents, respectively, these statistics show that the percentage of LGV driver fatalities, at 83 % of all occupants, is much higher than for cars (65 % of the fatalities are drivers) and bus occupants (7 % of the fatalities are drivers). This corresponds well to the number of occupants normally travelling in the respective types of vehicle. For this reason, it is particularly important to evaluate real accident data with a view to potential improvement of driver safety.

Figure 19 shows the distribution of the types of collision covered by the sample. In the case of multiple collisions, the collision which led to the greatest damage to the vehicle was chosen as the assigned collision type. As opposed to this, all accidents in which the vehicle was turned by at least a quarter of a revolution along its longitudinal or transverse axis were classified as being a “roll-over” collision, irrespective of the severity of associated additional collisions. In these figures, frontal collisions are by far the most frequent types of collision involving delivery vans.

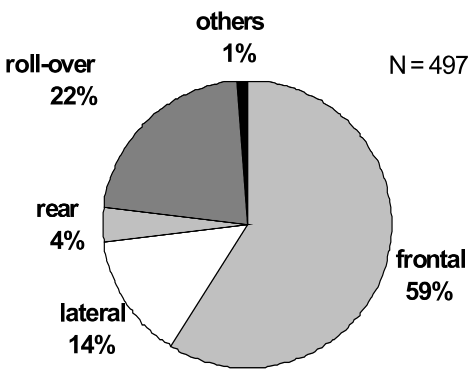

Figure 19: Type of collision, for 497 accidents involving delivery vans in Great Britain (Ford database)

The degree of utilisation of safety belts, as shown in Table 1, was determined mainly by investigating the vehicle after the accident, although the occupants were also questioned about this fact. Evidence that the driver had been wearing the safety belt was found in 47 % of all cases. A further 9 % of the drivers stated that they had been wearing the safety belt although this was not confirmed by the vehicle inspection. The proportion of passengers restrained is considerably lower than that of the drivers.

Table 1
Utilisation of safety belts by 902 delivery van occupants (Ford database)

Belt used	driver		co-driver		passenger		total	
	abs.	%	abs.	%	abs.	%	abs.	%
yes	233	47	4	11	71	18	308	33
claimed	46	9	5	14	17	4	68	7
no	151	31	16	46	244	62	411	45
not known	62	13	10	29	61	16	133	14
total	492	100	35	100	393	100	920	100

Risk of injury due to frontal collisions

Table 2 shows the effect of the other vehicle/object involved in the collision on the driver of the delivery van. The proportion of fatal (6 out of 13) and severe injured (MAIS 2+; 46 out of 99) to van drivers is very high especially in collisions with heavy goods vehicles (HGVs) and buses. This is particularly significant as the proportion of HGVs and buses in the entire number of vehicles on the road is only small.

Table 2
Van driver injury severity in relation to the other vehicle or obstacle involved in the accident, frontal collisions (Ford database)

other vehicle / obstacle	fatal	MAIS 2+	MAIS 1	MAIS 0	total*	
	abs.	abs.	abs.	abs.	abs.	%
car	2	37	83	19	143	46
HGV, bus	6	46	40	1	94	30
tree, mast or pole	1	5	25	4	35	11
wall, crash barrier, fence	1	5	10	1	17	5
others, not known	3	6	9	5	23	7
total	13	99	167	30	312	100

* contains 3 cases with unknown injury effects

The proportion of drivers who were protected by wearing a safety belt during a frontal collision is shown in Table 3. The belt utilisation quota for all cases has been determined to be 46 %, but 77 % of the drivers killed were not restrained when the accident occurred.

Table 3
Safety belt utilisation by drivers of vans involved in frontal collisions

Belt used	fatal	MAIS 2+	MAIS 1	MAIS 0	total*	
	abs.	abs.	abs.	abs.	abs.	%
yes	3	45	83	11	143	46
claimed	0	9	20	4	33	11
no	10	40	37	8	97	31
not known	0	5	25	7	37	12
total	13	99	165	30	310	100

* contains 3 cases with unknown injury effects

Injury risk of drivers and passengers on the struck side in lateral collision situations

The following findings relate to drivers passengers sitting on the outermost seat of a van on the side of impact in a lateral collision. In these accidents, the vans collided most frequently with cars (64 %), HGVs and buses (27 %), as shown in Table 4. The total number of cases studied is not sufficient to deduce statistically validated results, but a trend is perceivable: namely that the highest risk of injury occurs during single-vehicle collisions with poles/masts etc. and collisions with HGVs.

Table 4
Injury severity of van drivers and occupants seated on the side facing the collision in relation to the other vehicle or obstacle involved in the accident, lateral collisions

other vehicle / obstacle	fatal	MAIS 2+	MAIS 1	MAIS 0	total*	
	abs.	abs.	abs.	abs.	abs.	%
car	0	7	19	2	29	64
HGV, bus	2	2	5	3	12	27
tree, mast or pole	1	1	1	0	3	7
wall, crash barrier, fence	0	0	0	0	0	0
others, not known	0	0	1	0	1	2
total	3	10	26	5	45	100

* contains 3 cases with unknown injury effects

CRASH TESTS USED TO ANALYSE OCCUPANT SAFETY

Nowadays, the safety equipment of modern delivery vans is of practically the same quality as that in passenger cars. This has not always been the case. A comparison of the safety equipment of vans in the past ten years shows that the use of passive safety elements has increased considerably since Ford introduced the first series-equipment airbags in 1994 (WILHELMI, 2002). Nowadays, airbags for the driver seat are standard equipment in 90 % of all vans, the same applies to ABS or power-assisted steering. Airbags for the co-driver seat are available as options for almost all vehicles. Whereas, in the past, safety elements such as belt-pretensioners, belt force limiters, height-adjustable seat belts, lateral crash protection, differential locking, wing mirrors with wide-angle sectors and load-anchoring eyes in the cargo spaces were exceptions rather than the rule, they are now either standard equipment or at least available upon customer request.

A comparison of the safety equipment offered in different variants of the same vehicle model series has shown that minibuses are usually equipped with a wider range of safety devices than goods vehicles. Some manufacturers offer, for their minibus-versions, safety elements which they do not offer for the goods transport version of the same model. The Volkswagen T4 can be named as one example: the minibus version can be obtained with the “Electronic Stability Program ESP”, but this is not offered for the goods vehicle version. This illustrates that, due to a lack of market demand, there is still a need to adjust the standards of safety equipment for goods transport vehicles.

The following section describes three crash tests carried out by DEKRA’s accident research division on Ford Transit vans. These serve to illustrate the status of the interior safety of modern vans in frontal collisions using the same criteria as applied to cars. In addition, a crash test was carried out on an older-model Fiat Ducato pick-up truck at a lower collision speed. Up to date, only few results of delivery van and light goods vehicle crash tests have been published (BÜRGER, 1992). The Australian New Car Assessment Program (ANCAP CRASH TESTS, 2002) has provided some more recent results of crash tests with utility vehicles.

Full-frontal impact crash tests

Three tests were carried out with the vehicle hitting a rigid, non-deformable barrier with 100% of its width (so-called full frontal tests), the test data are given in Table 5. The occupants were modelled using instrument-bearing dummies of type Hybrid III (50^{th} percentile male) which were fastened in by safety belts. The driver seat was occupied during all tests. The Ford Transit vans also carried passengers on the co-driver seats. Test SH 02.018 was carried out with a so-called double passenger seat, so that two co-drivers (one in the middle, the other on the outside seat) could be placed in the vehicle.

In accordance with the American safety standards FMVSS 301 and 208 (currently valid up to 2003), the Ford Transits were crashed into the barrier at 48 km/h (30 mph). Both test vehicles were equipped with airbags for the driver's and outer passenger's seats. In test SH 02.018, the passenger on the middle seat was protected by a safety belt only.

Table 5: Synopsis of full-frontal impact tests

Test no.	Vehicle	Mass [kg]	Speed [km/h]	Occupants
SH 02.018	Ford Transit van, built 2001	2,460	48.1	Driver, passenger middle seat, passenger outer seat
SH 02.203	Ford Transit van, built 2001	2,350	48.4	Driver, passenger outer seat
SH 02.180	Fiat Ducato pick-up, built 1994	2,450	31.7	Driver

For the older model Fiat Ducato pick-up, a considerably lower collision speed, 32 km/h, was selected. The objective of this test was to obtain informative dummy stress data modelling a frontal collision in which the occupants could survive.

Figure 20 shows pictures of the progress of the collision in one of the Ford Transit tests. The unfolding of the airbag and the external deformation of the driver side of the vehicle can be seen.

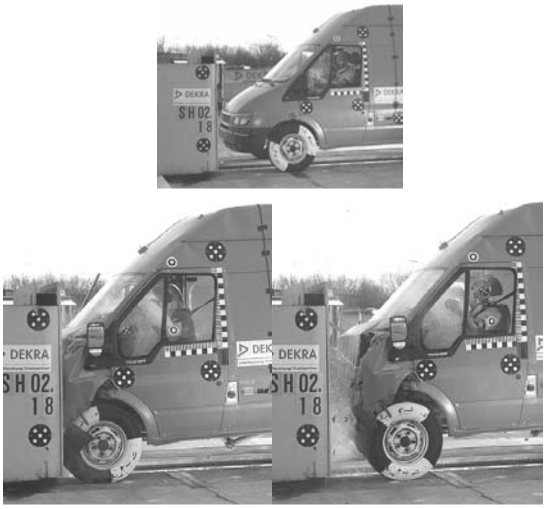

Figure 20: Progress of the collision during full-frontal test number SH 02.018 at 48.1 km/h

In line with the test conditions, the fronts of the vehicles were deformed over their entire widths, as shown in Figure 21.

The Ford Transit has two sturdy longitudinal frame elements. These contributed symmetrically towards absorbing the impact energy by converting it into deformation work. No fluids leaked from the tanks of either vehicle following the crash. The driver and passenger airbags of both Ford Transit vehicles were deployed. The survival space for the occupants remained virtually fully intact in all test vehicles. There were some folds to be seen in the floors/foot spaces of the vehicles. It was possible to open the driver and passenger doors of the two Ford Transit manually without tool – contrary to the doors of the Fiat Ducato, which had to be opened with a tool. In all tests, the dashboards / instrument panels showed traces of knee and lower leg impact by the dummies. For example, Figure 22 shows the situation in the region of the outer co-driver dummy's knee in the Ford Transit in test SH 02.018.

Figure 21: Deformation of the vehicle fronts (top picture: Fiat Ducato after impact at 31.7 km/h; centre: Ford Transit after impact at 48.1 km/h; bottom: Ford Transit after impact at 48.4 km/h)

Figure 22: Situation in the region of the outer co-driver's knee in a Ford Transit, showing traces of knee and shin impact, in test number SH 02.018

In addition, in test SH 02.018, carried out with three occupants, the head of the passenger dummy on the middle seat struck the instrument panel.

Except for the left-hand femur load measured in the Fiat Ducato, all measured dummy stresses were lower than the corresponding biomechanical limit values. Some of the measurement results are discussed below.

Figure 23 shows the values of the Head Injury Criterion (HIC). At a range between 423 to 561, these are far below the limit of 1000. In test SH 02.018, the value determined for the middle passenger, HIC = 550 showed a greater stress than those for the driver (HIC = 399) and the passenger on the outer seat (HIC = 423). This corresponds to the middle passenger's head striking the instrument panel. In test SH 02.203, the head stresses of both the driver (HIC = 559) and the passenger (HIC = 561) were roughly equal. In conjunction with the HIC evaluation of the driver of the older model Fiat Ducato, it must be remembered that this was tested at a lower collision speed.

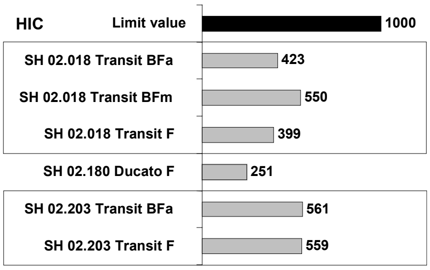

Figure 23: Head stresses of the dummies, determined as HIC values (F: driver, BFm: middle passenger, BFa: passenger on outer seat) , in comparison to the limit value

The thorax deceleration values, a_{3ms}, are shown in Figure 24. They range from 32 g for the middle passenger of the Ford Transit (test SH 02.018) to 40 g for the passenger on the outer seat of the Ford Transit (tests SH 02.018 and SH 02.203), and are also well below the limit value, which is 60 g in this case.

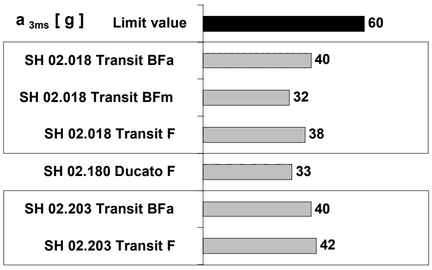

Figure 24: Thorax deceleration values, a_{3ms}, experienced by the dummies, in comparison to the limit value

The values of the longitudinal forces measured in the left-hand femur of the dummies are quite remarkable, as shown in Figure 25. In the Fiat Ducato, the value obtained was 10.5 kN, which is in the region of the 10 kN limit for this criterion. This corresponds to the knee striking the dashboard, behind which there is a sturdy cross-member. The other values, which are between 1.0 and 2.2 kN, are well under the limit.

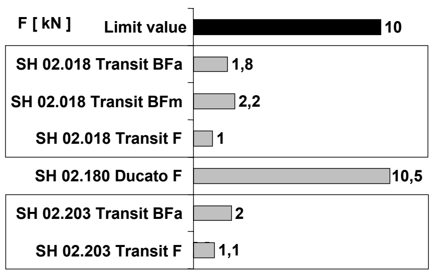

Figure 25: Maximum compressive forces F measured in the left femur of the dummies, in comparison to the respective limit value

One of the vehicles (test SH 02.018) was subjected to a so-called static roll-over test in order to check the leak-tightness of the tanks in accordance with FMVSS 301 (Figure 26). In this test, the vehicle is rotated, in stages, about a longitudinal axis by two full revolutions. After each quarter of a turn, i. e. in the 0°, 90°, 180° and 270° positions, the vehicle is held stationary for 5 minutes. During this test, not more than 142 g of fuel per 5 minute period may leak out. The vehicle passed this test.

Figure 26: Test to check for tank leakage in accordance with FMVSS 301

Offset-test with an overlap of 40%

A further Ford Transit van (of mass 2,502 kg, built 2000) was subjected to a so-called offset test with 40% of the front striking a fixed rigid barrier fitted with a deformation element at 56.2 km/h. This test is defined in the European regulation ECE-R 94. As in the full-frontal test SH 02.018, the vehicle was equipped with airbags for the driver and the passenger seats. Dummies of type Hybrid III (50th percentile male), were fastened in on the driver seat and the middle and outer passenger seats by means of the safety belts. Figure 27 shows the progress of the crash. The unfolding of the airbag and the external deformation of the driver side of the vehicle can be seen.

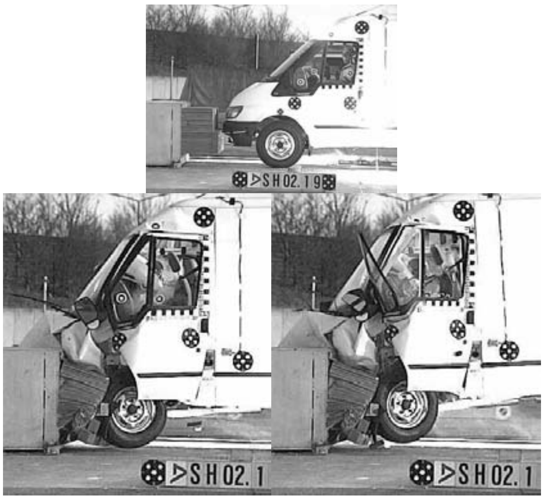

Figure 27: Progress of the collision during offset test SH 02.019 at 56.2 km/h

The one-sided action of the impact forces on the front of the vehicle is a typical characteristic of offset crashes. Correspondingly, the longitudinal frame element being directly hit has to convert more of the impact energy than the one on the side away from the impact. Figure 28 shows the deformed vehicle in the final rest position.

Figure 28: Front of the Ford Transit, shown in the final position after collision at 56.2 km/h and with a 40% coverage of the obstacle in an offset crash test

Although there are no safety-relevant legal regulations concerning goods vehicles with respect to offset crash tests, the Ford Transit also showed structural characteristics in this test which were generally acceptable. The occupant cell did not break apart. The foot space was damaged more severely in front of the driver's seat than during the full-frontal tests. The floor was folded in the driver's area. Both the steering wheel and the pedal assembly intruded further into the inner space than after the full-frontal tests of the same vehicle type.

The driver-side door was jammed and could only be opened manually with much greater force (a force of 800 N was measured) after unlatching the door from the inside of the vehicle. The passenger's survival space was virtually completely intact. The passenger door could be opened manually with normal effort and without tools. The instrument panel / dashboard showed traces of being struck by the knees and lower legs of all three dummies. The head of the dummy on the middle seat had struck the instrument panel. Both airbags had been deployed and had helped to restrain the driver and outer passenger.

All measured dummy stresses were below the respective biomechanical limits. To illustrate this, Figures 29 to 31 show the measured HIC, thorax deceleration a_{3ms} and the maximum compressive forces in the left thigh. The value ranges are: HIC = 112 - 229, a_{3ms} = 27 - 38 g and F = 0.9 - 3.9 kN.

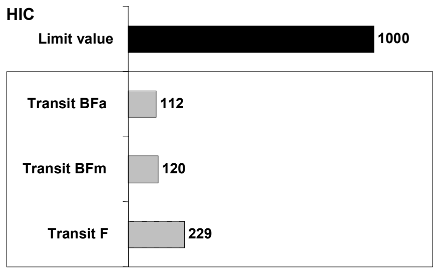

Figure 29: Head stresses of the dummies, determined as HIC values (F: driver, BFm: middle passenger, BFa: passenger on outer seat) determined in offset crash test SH 02.019

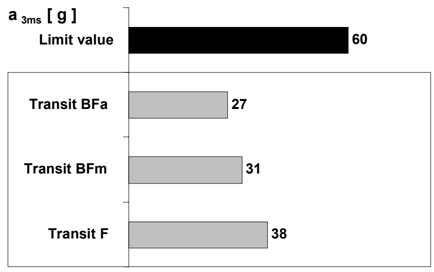

Figure 30: Thorax deceleration values, a_{3ms}, experienced by the dummies, determined in offset crash test SH 02.019

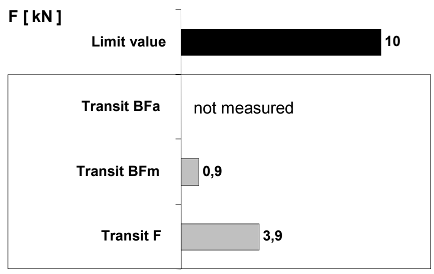

Figure 31: Maximum compressive forces F measured in the left femur of the dummies, determined in offset crash test SH 02.019

Generally speaking, the offset crash test shows that light goods vehicles (LGVs) have not yet completely achieved the same high safety standards as modern car designs. Although the legal requirements on goods vehicles with respect to passive safety will not be made any stricter within the foreseeable future, vehicle manufacturers are committed to continually improving the safety of such vehicles.

BRAKE TESTS FOR ANALYSING ACHIEVABLE DECELERATION VALUES

In addition to passive safety, the active safety of delivery vans is being widely discussed. In order to examine the braking capacity of modern vans compared to that of passenger cars, appropriate trials according to ECE-R 13 were carried out at the DEKRA Automobile Testing Centre (HÄUSSERMANN, 2003). The vehicles used in the trials were a Fiat Ducato Maxi 2.8 idTD, a Mercedes Sprinter 311 CDI and a Renault Master 2.5 dCI. An identical model of each of these vehicles is made by other manufacturers (Fiat: Citroen and Peugeot, Mercedes: Volkswagen, Renault: Opel and Nissan), meaning that the results of the test series can be regarded as being representative. The trials were carried out on dry tarmac surfaces on the test tracks of the Euro Speedway Lausitz at an ambient temperature of 4°C. The vehicles used the tyres fitted by the respective car dealer (Renault Master: Michelin all-round tyres, Fiat Ducato: Pirello summer tyres, Mercedes Sprinter: Continental summer tyres). As a comparison, a car - VW Polo - was tested under identical conditions. All vehicles were fully loaded, and the maximum permissible axle load was used to the full in each case. First of all, three tests were carried out at a speed of 100 km/h using cold brakes. Then a further three test series were carried out at an initial speed of 130 km/h, also with cold brakes. Finally, a test was carried out with warm brakes from a speed of 100 km/h. To warm up the brakes, 16 full braking manoeuvres in which the vehicle was brought to a total standstill from 100 km/h were carried out in quick succession.

Figure 32 shows the braking distances, whereby only the best value is shown for those tests involving several braking manoeuvres per vehicle at the same conditions. With cold brakes, the braking distances of all vehicles were very similar, both at initial speeds of 100 km/h – the values being between 50.1 m (Mercedes Sprinter) and 54.4 m (Fiat Ducato) and at 130 km/h – where the values ranged from 80.5 m (Renault Master) to 88.2 m (Fiat Ducato). In a direct comparison, no difference between the braking capacity of the vans and that of the car could be identified.

In the trials with warm brakes out of 100 km/h, the braking distance of the VW Polo, namely 49.6 m, was considerably shorter than the braking distance of the vans, namely between 58.0 m (Fiat Ducato) and 59.9m (Renault Master). On the one hand, this indicates a reduced braking performance of the vans under the extreme conditions given here. On the other hand, one must take into consideration that at a braking distance of 59.9 m from a speed of 100 km/h, the mean deceleration to a complete stop according to ECE-R13, was still 8.1 m/s^2. This is considerably higher than the values required by ECE, which for braking manoeuvres using the driving brake system and with the engine running but no gear engaged, are between 5.0 and 5.8 m/s^2, depending on the vehicle category.

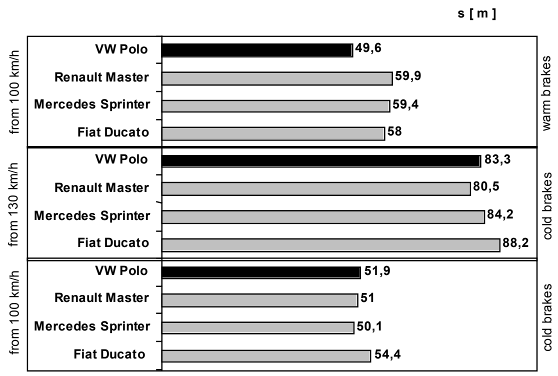

Figure 32: Braking distances obtained for three delivery vans (Renault Master, Mercedes Sprinter, Fiat Ducato) and a car (VW Polo) in brake tests carried out according to ECE-R 13 under identical conditions.

SUMMARY AND OUTLOOK

In the 1990s, both the number of registered light goods vehicles (up to 3.5 t permitted gross mass) and their rate of involvement in accidents with casualties increased considerably. In Germany, between 1992 and 2001 the number of registered vehicles of this type rose by 75% and their involvement in accidents with casualties by 64% (urban areas) and 80% (Autobahnen), respectively. In accordance with manufacturers' sales figures and the high demand for transport services in the courier and postal sectors, one can assume here that the so-called "delivery vans" play a large role. Against this background, there is a need to investigate the involvement of these vehicles in accidents and their safety, since this category is not treated as a separate group in the *(German)* registration and accident statistics. Up to now, too little is known about the involvement of these vans in accidents and about risk characteristics in relation to their number and specific mileage.

The DEKRA accident research team has been investigating accident occurrences with delivery vans since the late 1990's. In a pilot study, an accident database for these vans was established. This currently contains data on 166 cases. From these data, we know that cars are the most frequent counterpart in accidents involving vans, that in the second largest group of accidents only the van is involved and in the third, the van collides with a heavy truck or lorry. With regard to the type of accident/type of occurrence causing the accident, accidents in the direction of traffic flow are the most common, then turning-off / road crossing accidents, and then accidents in which the driver has lost control of the vehicle. On the whole, frontal collisions are the most frequent type of collision involving delivery vans.

Among measures currently being discussed with a view to reducing the number and severity of accidents involving delivery vans, is a technical limitation of speed to 130 km/h in small vans (up to 3.5 t). In the case of larger goods vehicles/vans (permitted gross mass of 3.5 t to 7.5 t) registered as goods vehicles (LKW) a speed limit of 80 km/h has been imposed for some time now. An evaluation of the reconstructed driving and collision speeds of vans involved in accidents recorded in the DEKRA database shows that less than 5% occur in the speed range above 130 km/h, and that these accidents could hardly have been avoided even if there had been a technical limitation of the maximum possible speed of light transport vehicles to 130 km/h. As the evaluation of the official accident statistics also shows, most accidents involving goods vehicles occur in towns or on main country roads. This means that the potential benefit of speed limiters set to 130 km/h maximum speed in vans would be restricted to preventing a very small number of accidents caused by excessive speeding on motorways.

In agreement with official statistics, the DEKRA cases show that the drivers of small vans cause accidents more frequently than the average driver. In this respect, further systematic analyses of the accidents with relation to accompanying driving behaviour of the drivers as well as targeted training measures are necessary. In this connection, the possible regulation of driving and rest times for delivery van drivers should be considered.

As part of Ford's European accident research work, the Vehicle Safety Research Centre of the University of Loughborough, commissioned by the Ford Motor Company, has collected and evaluated the data of approx. 500 van accidents in Great Britain. These examinations, too, show that 59% of van accidents are usually head-on collisions. Here, too, the collision counterparts are mainly cars (64%). In 27% of all cases the van collided with a heavy goods vehicle. The most severe injuries incurred by van occupants resulted from collisions with heavy goods vehicles and stationary objects.

In the accidents studied in Great Britain, the use of safety belts was very low in vans (50% for drivers, 30% for other occupants). Similar results are also available for Germany. Observations made by the DEKRA accident research team in 1999 on main country roads showed that only around 18% of the occupants of light transport vehicles (mainly vans) were restrained. In other observation studies carried out on motorways in 2001, the percentage of restrained occupants of light goods vehicles was 38%. These figures are much lower than the figures for safety-belt use in cars, in which more than 90% of drivers and adult front-seat passengers have been regularly using their safety belts since the mid-80's, according to the German Federal Road Office. It is a major aim therefore to encourage the use of safety belts in light goods vehicles. In September 2002, at the International Automobile Fair (IAA) in Hannover, the German Traffic Safety Council (Deutscher Verkehrssicherheitsrat, DVR) launched the campaign "Has it clicked?" together with the trade association for vehicle use, DEKRA and other partners. This campaign also targets van drivers.

Passive safety in modern small vans has already reached a very high level, especially for occupants who are restrained. This was documented by a trial using a Ford Transit in three crash tests (two full-frontal and one offset) in the DEKRA crash centre. In the full-frontal test against a rigid barrier at a collision speed of 48 km/h, the body structure withstood the crash stresses very well. The survival space for the occupants remained intact. All loads on the driver and two front-seat passengers remained below the biomechanical limits. Also in the offset crash, all dummy loads remained below the corresponding limits. The results of an asymmetrical load test fell slightly short of the high level of safety achieved in modern car design. In a comparison full-frontal test in which an older-model Fiat Ducato pick-up truck crashed into a rigid barrier at 32 km/h, distinct improvements in the interior safety of modern delivery vans can be distinguished.

The braking performance of modern vans in comparison to a car was examined in brake tests. Here, no difference could be found in cold brake tests from 100 and 130 km/h. In warm brake tests from 100 km/h, slightly shorter braking distances were measured for the car than for the vans, even though the average deceleration to a complete stop of these reached the high value of 8.1 m/s^2.

Although no tightening of the legal requirements is expected in the near future, the vehicle manufacturers have dedicated themselves to continually improving the safety of these vehicles, too. As with heavy commercial goods vehicles, a lot of delivery vans nowadays are the driver's place of work, making the driver's safety all the more important.

Vans are often described in the media as the new "menace on the roads". This is counterproductive in view of the traffic space becoming more and more crowded. What is needed is a partner-like relationship among all types of road users in order to avoid accidents and guarantee the flow of traffic. Here, drivers of commercial vehicles, being the "professionals", have a special responsibility towards other road users and themselves as well as to their vehicle and cargoes. Special driver training and improved vehicle technology contribute to improving safety and the image of the delivery van as an indispensable part of fast and flexible commercial road traffic. Accident research work contributes by systematically analysing and presenting results, and by discussing findings and providing appropriate suggestions for improvement.

REFERENCES

AAAM (1990): The Abbreviated Injury Scale: 1990 Revision, Association for the Advancement of Automotive Medicine, Des Plaines, Illinois, 1990

ANCAP Crash Tests 2002 Results Utilities:. http://203.147.151.126/motoring/cars/crash_tests/ancap/ute.shtml

BERG F.A., AHLGRIMM J, KUGELE M, MATTERN R., MILTNER R: Interdisziplinäre Beantwortung von Fragestellungen zur Airbag-Thematik im realen Unfallgeschehen durch Sachverständige und Unfallforscher. Verkehrsunfall und Fahrzeugtechnik 40 (2002) Edition 3, pp 71-79 and Edition 6 pp 169-175

BÜRGER H.: Vergleich der Crashworthiness zwischen Fahrzeugen in Frontlenker- und Kurzhaubenbauweise - dargestellt am VW Bus der 3. und 4. Generation. VDI-Berichte (VDI Reports) No. 968, Düsseldorf 1992

DIN 70010: Systematik der Straßenfahrzeuge - Begriffe für Kraftfahrzeuge, Kraftfahrzeugkombinationen und Anhängerfahrzeuge, April 2001, FAKRA/Band 1/10 Delivery date June 2001 in Beuth Vertrieb

DTLR: Road Accidents Great Britain: 2000, The Casualty Report. The Stationery Office, London 2001

GRANDEL J., BERG F.A., NIEWÖHNER W., Sicherheitsanalyse in Straßengüterverkehr. Berichte der Bundesanstalt für Straßenwesen, Series "Mensch und Sicherheit" Edition M7, April 1993

HÄUSSERMANN M.: Heißes Eisen, Sicherheit Transporter Bremstests. Lastauto Omnibus, (Edition 1 January 2003, ETM Verlag, Stuttgart

LENARD et. al. An overview of accidents and safety priorities for light goods vehicles, Proceedings of the Vehicle Safety 2002 Conference, Institution of Mechanical Engineers 28-29. May 2002, London

NIEWÖHNER W., BERG F.A., FRONCZ M.: Unfallgeschehen mit Transportern in Deutschland - Ergebnisse einer Pilotstudie. Conference summary. DEKRA Symposium Passive Safety in Commercial Vehicles 5.-6. October 2000, Neumünster

NIEWÖHNER W., BERG F.A., FRONCZ M.: Accidents with vans and box-type trucks (transporters): Results from official statistics and real life crash analyses. Paper ID-No. 316, Proceedings 17th International Technical Conference on the Enhanced Safety of Vehicles, Amsterdam, June 4-7, 2001

RÜCKER P., BERG F.A., NIEWÖHNER W., SFERCO R., FAY P., SCHRIEVER T.: Safety of transport vans - results of accident analysis and crash tests. 3. DEKRA Symposium Passive Safety in Commercial Vehicles 17.-18. October 2002, Neumünster, Conference summary

Statistisches Bundesamt: Fachserie 8, Serie 7, Verkehrsunfälle, Verlag Metzler-Pöschl, Stuttgart.

WILHELMI T.: Untersuchung des Unfallgeschehens und der passiven Sicherheit von Transportern. Dissertation at Technical College (Fachhochschule), Wiesbaden and the DEKRA Accident Research Centre, Stuttgart 2002